United States Patent

[11] **3,583,352**

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[21] Appl. No. **834,337**
[22] Filed **June 18, 1969**
[45] Patented **June 8, 1971**
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Paris, (Seine), France
[32] Priority **Dec. 24, 1968**
[33] **France**
[31] **180260**
Continuation-in-part of application Ser. No. 751,273, Aug. 8, 1968, now abandoned.

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[54] **SUPPORTING DEVICE FOR SELF-CARRYING CYLINDRICAL OR SPHERICAL STORAGE TANKS AND ITS VARIOUS APPLICATIONS**
26 Claims, 13 Drawing Figs.

[52] **U.S. Cl.** **114/74, 220/15**
[51] **Int. Cl.** **B63b 25/08**
[50] **Field of Search** ..... 114/74 A; 220/9 A, 15

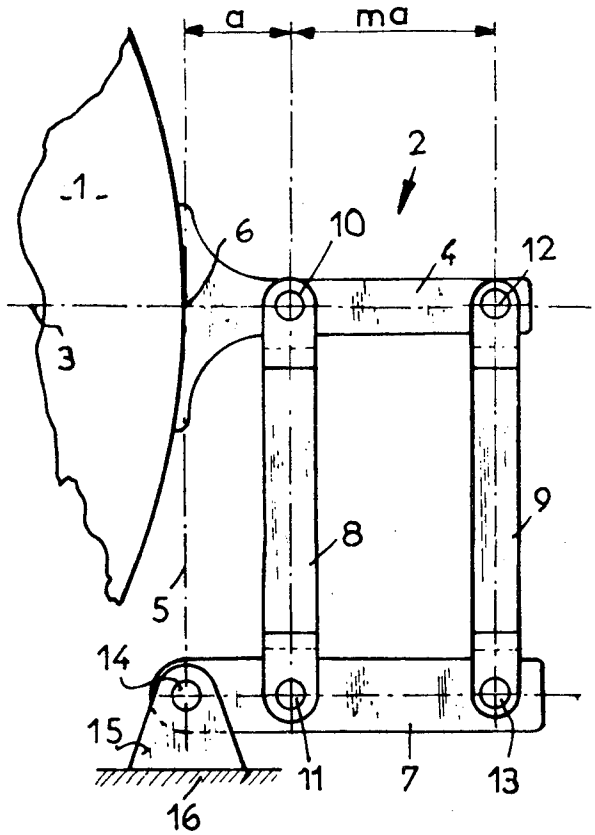
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Primary Examiner—Trygve M. Blix
Attorney—Nolte and Nolte

ABSTRACT: An arrangement for supporting a cylindrical or spherical rigid tank comprising several spaced bearing devices distributed about said tank and comprising each one a horizontal bracket member integral with and projecting radially outwards from said tank in its horizontal axial or diametral plane, a horizontal arm below and parallel to said bracket member and pivoted to a fixed fulcrum in the vertical plane tangent to the geometrical envelope of the neutral fibers of the tank wall and two parallel links spaced outwards from said fulcrum and pivoted to said bracket member and arm to form a deformable vertical parallelogram.



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Fig: 1.

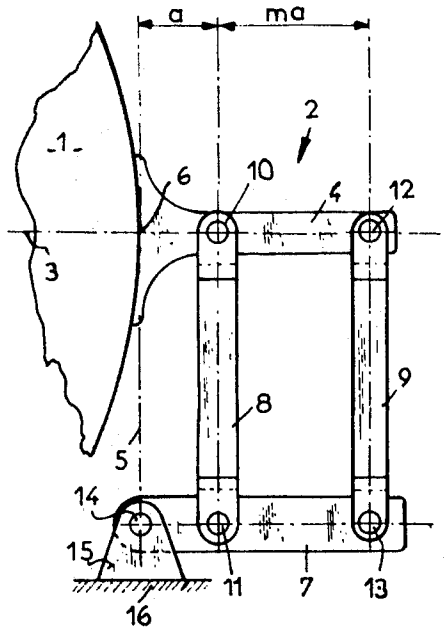


Fig: 2.

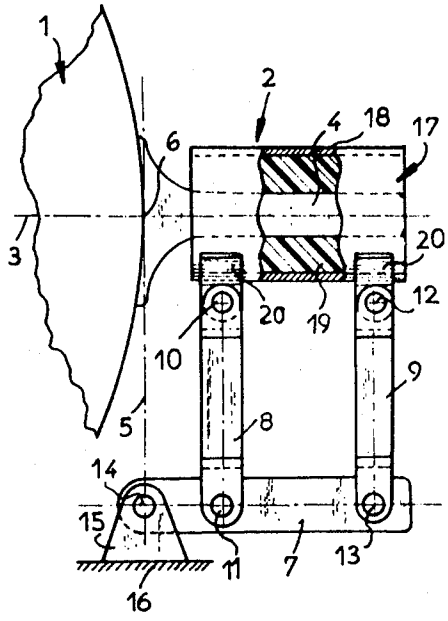


Fig: 3.

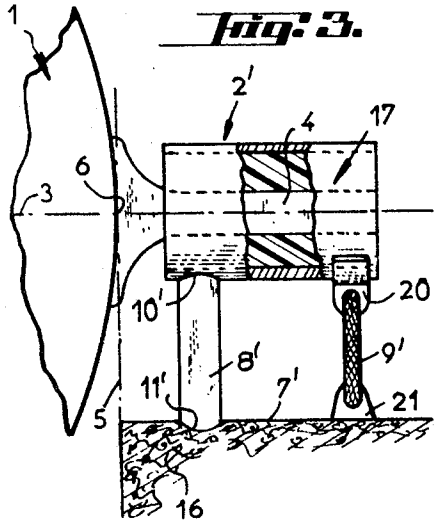
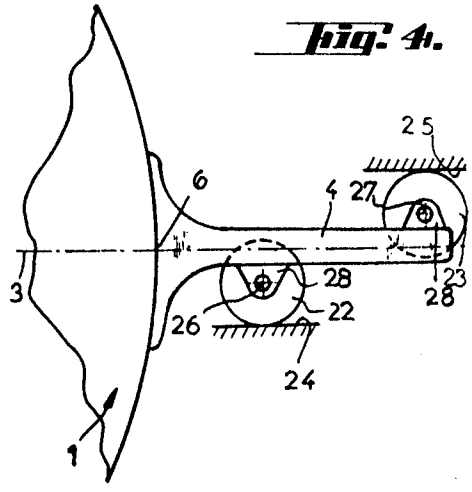


Fig: 4.



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fig: 5.

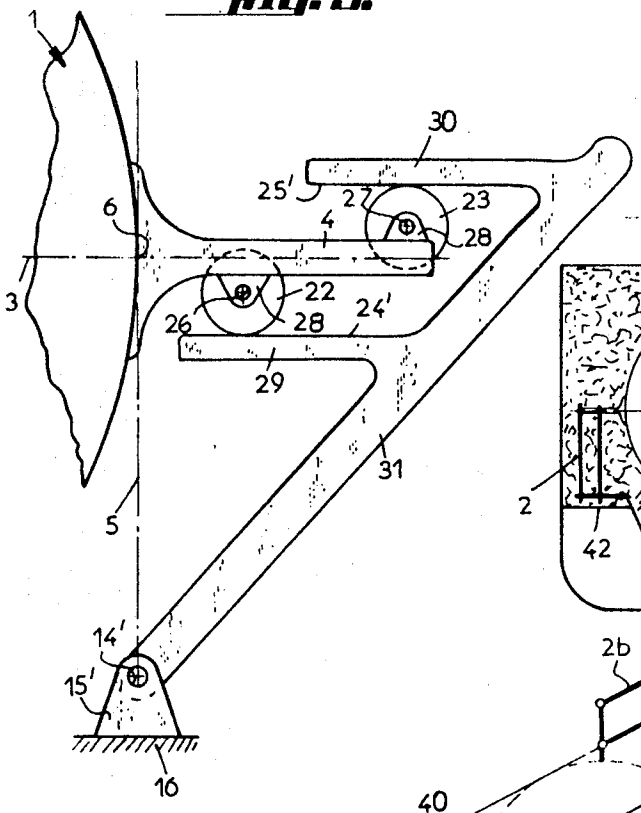


fig: 6.

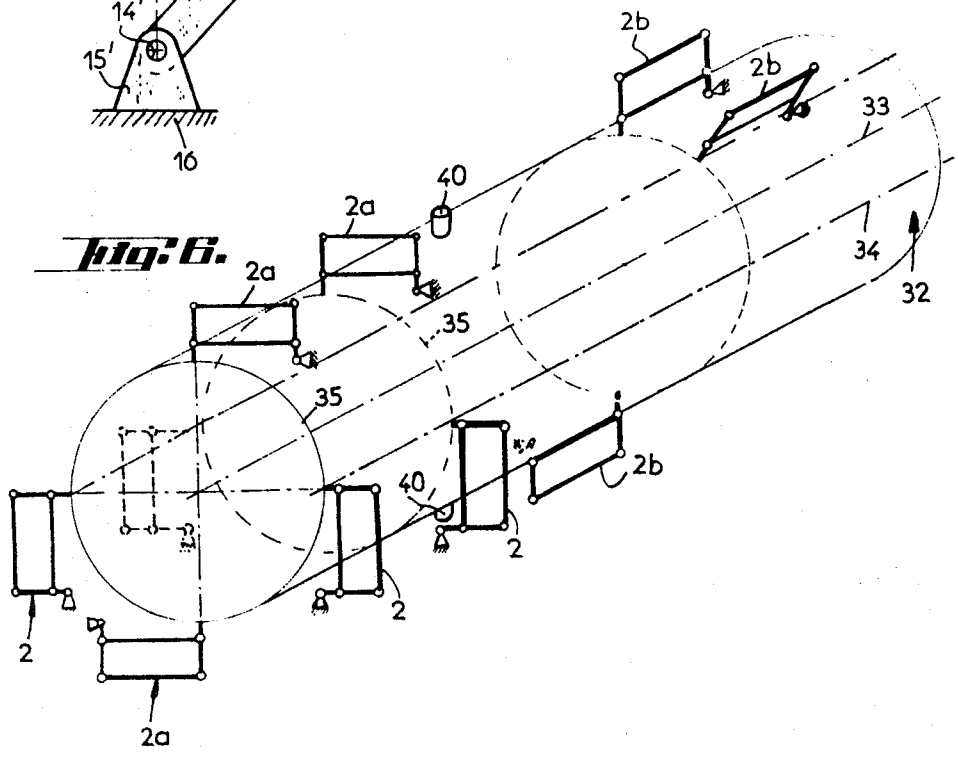
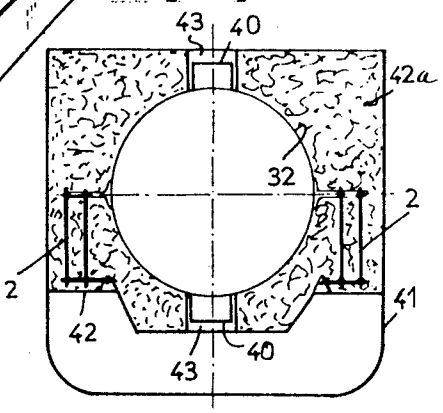


fig: 6.



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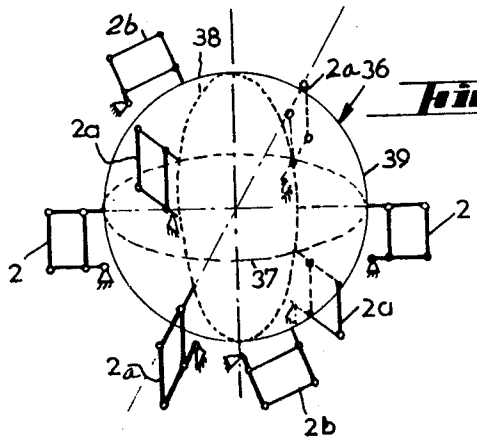
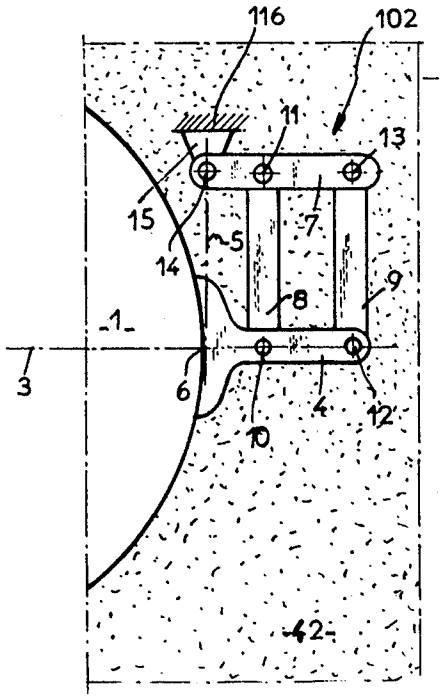


Fig: 7.

Fig: 9.



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Fig. 13.

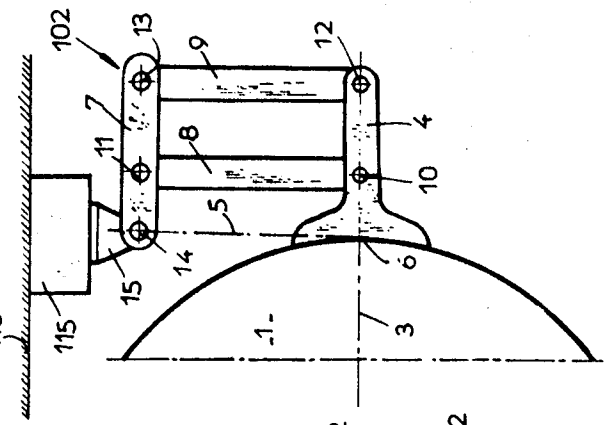


Fig. 12.

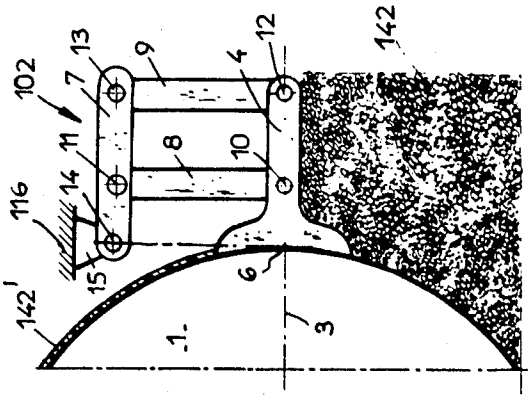


Fig. 10.

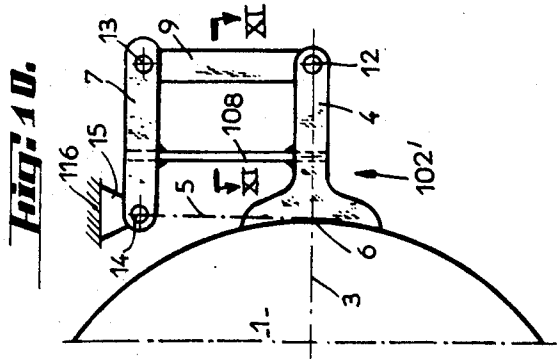
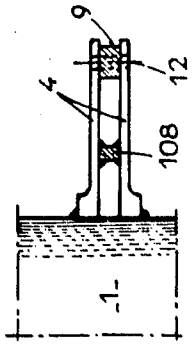


Fig. 11.



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SUPPORTING DEVICE FOR SELF-CARRYING CYLINDRICAL OR SPHERICAL STORAGE TANKS AND ITS VARIOUS APPLICATIONS

This is a continuation-in-part of applicant's copending U.S. Pat. application Ser. No. 751,273 filed Aug. 8, 1968 and now abandoned.

The present invention relates essentially to an assembly or arrangement forming a support for a storage, preservation and/or transportation or conveying tank, vat, cistern, vessel or like container with a shell, casing or envelope which is substantially a solid of revolution at least about one geometrical axis which is at least approximately horizontal in the normal position and having preferably a substantially cylindrical or spherical shape, said tank having at least one outer substantially rigid wall of substantially self-supporting structure or construction and said support pertaining to the type consisting of a plurality of main outer bearing devices, distributed at discrete locations about said tank. The invention is also concerned with the various applications and uses resulting from putting said support into practice.

From the prior state of the art, it is known that tanks having a shape of a solid of revolution and in particular a substantially cylindrical or spherical shape are especially adaptable to the storage or transportation of fluids and particularly of cryogenic or strongly cooled liquids, such as liquefied natural gases as methane for example, stored or preserved at their vapor pressure at very low temperature. Such tanks are particularly adapted for bulk storage on land, i.e. at stationary locations or fixed positions, as well as for in particular waterborne transportation or conveyance (by sea or water ways), in which case these tanks are mounted and erected permanently as vessels or like containers on board and in particular within the holds of floating vehicles, appliances or contrivances, such as cargo boats or ships and freighters, barges, lighters and equivalent or like vehicles. These tanks may however be also mounted on rolling vehicles for transportation by land either by road, such as automotive tank lorries or tank wagons, motor trucks and carriages, motor vans, trailer cars or the like, or by railway, such as railway wagons and cars or the like. More particularly in the case of storage tanks for strongly cooled fluids, such as liquefied natural gasses, such tanks are obviously suitably heat-insulated and all parts in direct contact or thermal conduction with the contained fluid are generally made from noble hence relatively expensive materials, such as stainless steels, for example, likely to exhibit a satisfactory behavior or retaining a good mechanical strength at the very low operational temperatures.

To keep or retain all the advantages inherent with the specific geometrical shape of such tanks, it is necessary to support the latter in such a manner that they are not subject when in use in particular to excessively high or too severely concentrated stresses or strains under the action of either statical or dynamical loads and other active or passive, outer or applied forces to which they are likely to be subjected. Thus care should be taken to avoid local parasitic efforts as well as any rigid fastenings, connections, anchorings, attachments or securings, likely to hinder, impede or even possibly prevent the thermal deformations of the tank which may be produced periodically or intermittently under working conditions or operating circumstances.

A main object and purpose of the invention is to propose a correct and satisfactory solution to this problem by providing a support which is characterized in that each aforesaid main outer bearing device is rigidly affixed to said self-supporting tank envelope or shell by at least one structural element invariably connected directly to the outer wall or surface thereof, substantially at the level at least of the horizontal, axial or diametral plane of said tank in its normal position, said elements being distributed in spaced relationship along the corresponding meridian line of the tank and supported each one by a stationary part, so that the passive bearing reaction or supporting forces, statically balancing the weight of said tank and of its contents, are at least approximately tangent, respectively, to the geometrical envelope surface of the neutral fibers of the tank wall while having their application points located substantially within this surface, variable connecting means which couple at least some of said elements to associated fixed parts, being preferably provided for achieving a sufficient local relative mobility, consistent with a free thermal deformation of the tank.

Such an arrangement is advantageous since the three conditions of supporting, defined hereinabove, are necessary and sufficient and practically solve the technical problem set forth hereinabove perfectly. In effect, if the first aforementioned requirement is not met, i.e. if the bearing points of the tank upon its support are located outside, for example underneath, the horizontal diametral plane of the cylindrical tank or the equatorial plane of the spherical tank, the supporting reactions, directly opposed to the weight of the tank, which thus are not tangential to the wall thereof, produce a field of local parasitic compression forces directed inwards of the tank, thereby tending to cause the tank wall to be locally driven in at the location of each aforesaid bearing device. Furthermore, if the second aforesaid requirement is not met, i.e. if the supporting forces have not their application points lying along the neutral fiber of the tank skin or sheet, hence within the very metal thereof, then there is provided a lever arm for the system of bearing reaction forces the directions or lines of action of which are spaced radially towards the outside of the tank wall, thereby producing a parasitic bending moment inducing undesirable local flexure or bending stresses and strains. Finally, inasmuch as the tank is adapted to contain a cryogenic fluid, the supporting device according to the invention enables to satisfy the third aforementioned requirement, since it allows the free thermal contraction or expansion of the tank.

According to a further characterizing feature of the invention, in the case of a tank the relative position or orientation proper of which varies periodically about its center of gravity owing to various parasitic or disturbing, intermittent motions of rotation, moving or displacing it away from its normal position of stable equilibrium, at least one set of auxiliary or additional bearing devices is associated to each separate geometrical axis of rotation, so that at least the points at which said element of each set are rigidly attached, fastened, affixed, connected or secured to said tank respectively lie within a same plane substantially perpendicular to the corresponding axis of rotation and are distributed along the trace of intersection of this plane with the tank wall to produce additional bearing reactions capable of at least assisting in balancing the weight of the tank and of its contents in its temporarily deflected, deviated or turned aside position.

According to still another characterizing feature of the invention, in the case of an aforesaid tank undergoing rolling and pitching motions, respectively, and for example mounted on a floating, rolling or flying vehicle or contrivance, the longitudinal, normally substantially horizontal, direction of which is parallel to the axis of revolution of said tank, a plurality of said auxiliary bearing devices are distributed respectively on the one hand within at least one radial plane which is vertical or perpendicular to said axis of rotation, along its corresponding circumference of intersection and on the other hand within the vertical meridian plane along the trace thereof on the tank wall.

This arrangement is particularly advantageous in the case of tanks mounted or installed on or within transportation vehicles, as for example within a ship's hold, since the tangential supporting within a substantially horizontal, diametral or equatorial plane, enables to transfer or to transmit the weight of the tank and of its contents efficiently and effectively to the bottom end wall or side structure of the ship's hull. The dynamic effects of rolling pitching are received and absorbed or balanced by a supporting system of equivalent design, provided along two great circles substantially orthogonal to the ship's longitudinal axis and athwartship axis, respectively, in

the case of a spherical tank or along one or several diametral planes and in particular within the vertical diametral plane parallel to the longitudinal medial plane or plane of symmetry of the ship and along transverse parallel circles in the case of a cylindrical, for example right circular, tank.

According to still a further characterizing feature of the invention, each aforesaid structural element forms a substantially straight restrained beam, bracket member, overhung girder or cantilever girder directed or extending outwards in overhanging relationship along a direction which is substantially radial or normal to the wall or outer surface of said tank.

According to still a further characterizing feature of the invention, each aforesaid bearing device consists of a deformable assembly forming a kind of parallel motion or plane linkage parallelogram, one longitudinal side or rod of which is at least one portion of said bracket member, cantilever girder or restrained overhung beam and the opposite side is connected to a stationary outer fulcrum or support construction, whereas one of the transverse sides, which is axially compressed, consists of a substantially rigid bar, link or rod and the other transverse side, which is axially under tension, is formed by a rod or a flexible tie or bond such as a wire rope, a chain or the like, forming a stay or brace.

In the case of tanks for storing strongly cooled fluids, it is advantageous according to still a further characterizing feature of the invention that each aforesaid restrained overhung beam, cantilever girder or bracket member be thermally insulated from its connection with the remainder of the associated device, which remainder is made of substantially ordinary building or engineering materials or steel, thereby allowing to cut down the expenditures and the cost price of the support.

The invention is therefore of a very simple construction, hence of unexpensive building, economical manufacture and efficient, reliable and dependable operation.

The invention is also concerned with the various applications and uses resulting from reducing said support to practice, in particular, in connection with stationary storage tanks and travelling or transportation tanks for fluids kept at temperatures differing very much from the normal ambient or room temperature for example strongly cooled fluids such as liquefied natural gases, as well as with the tanks, vehicles, equipments and plants provided with such devices.

The invention will be better understood and further objects, purposes, characteristics, details and advantages thereof will appear as the following explanatory description proceeds with reference to the accompanying diagrammatic drawings, given by way of examples only, illustrating several forms of embodiment of the invention and wherein:

FIG. 1 shows an outer side view of a main bearing device substantially in the shape of a deformable or hinged parallelogram according to one embodiment of the invention, for supporting a cylindrical or spherical tank only one portion of which, broken away from the outer rigid or self-supporting wall, is visible;

FIG. 2 is a similar view partially in section with parts broken away, of an alternative embodiment or modification of the main bearing device wherein the restrained overhung beam, cantilever girder or bracket member is thermally insulated from the remaining structure of the device by a heat-insulating sleeve, jacket, casing, muff, lagging or like cushion or pad;

FIG. 3 is a similar view of still another alternative embodiment of the aforesaid main bearing device;

FIG. 4 shows a similar view of still another embodiment of said main bearing device wherein the restrained overhung beam, cantilever girder or bracket member is provided with opposite rollers or wheels in engagement with stationary parallel runways or tracks;

FIG. 5 is a similar view of a modification of the preceding bearing device wherein the guiding roller paths, runways or tracks are carried by a support pivotally connected to a stationary structure;

FIG. 6 is a diagrammatic outer separate, perspective view of a cylindrical tank assumed to be mounted on board a ship and showing the main bearing devices and auxiliary (antirolling and antipitching) bearing devices, respectively;

FIG. 7 is a view similar to the preceding one, showing a spherical tank mounted aboard a ship and provided with its main and auxiliary (antirolling and antipitching) bearing devices;

FIG. 8 shows at a smaller scale, a cross-sectional view of a ship the hold of which contains a cylindrical tank having its horizontal axis of revolution directed longitudinally of the ship and which is supported by devices according to the invention;

FIG. 9 is an external elevational side view of an alternative embodiment of a hanging or depending supporting device for a cylindrical or spherical tank suspended therefrom, only one portion of which is visible, said device forming a kind of parallel motion, hinged or toggle parallelogram;

FIG. 10 is a similar view of a modification, wherein the vertical side of said parallelogram which is nearest to the tank, is rigidly secured to the horizontal sides of said parallelogram;

FIG. 11 is a fragmentary view in cross section taken upon the line XI–XI of FIG. 10;

FIG. 12 is a similar view of a further alternative embodiment wherein each supporting device, carrying the tank weight, is substantially entirely free from or clear of the heat insulation;

FIG. 13 is a similar view of still a further embodiment wherein the hanging supporting device is heat-insulated from the outer stationary supporting structure.

According to the exemplary form of embodiment of FIG. 1, the reference numeral 1 generally denotes a portion of the outer rigid or self-supporting wall either of a spherical tank or of a cylindrical tank with a substantially horizontal axis of revolution in the normal position of the tank. This tank is supported by a series of main bearing devices one of which is shown here and generally designated by the reference numeral 2 and which are for example substantially uniformly distributed about the tank along the trace of intersection of the horizontal diametral or equatorial plane 3 thereof.

Each bearing device comprises a relatively stiff or rigid bracket member 4, forming a restrained overhung beam or cantilever girder, which is substantially horizontal in the normal rest position of the tank while extending or being directed substantially radially or normally with respect to the wall or outer surface 1 thereof. This bracket member 4 is rigidly secured, affixed, connected or fastened, as by welding, to the tank wall, so that its longitudinal medial axis extends substantially radially and lies within the horizontal diametral or equatorial plane 3. Thus, the plane, denoted by its trace 5, which is tangent at the mean point 6 of contact or of connection between the tank 1 and the bracket member 4, is substantially vertical and tangent to the neutral fiber or line of the wall.

In the example shown, the bearing device 2 is formed of a deformable, hinged or toggle parallelogram lying substantially in the vertical plane normal at point 6 to the tank wall surface 1. This parallelogram, which in the normal rest position at ambient temperature, has substantially the shape of a rectangle, has a pair of opposite longitudinal sides, namely an upper or top side formed of the bracket member 4 and a lower or bottom side formed of a rigid bar, rod or the like 7, as well as a pair of opposite transverse sides 8, 9. formed each one of a rigid link or rod pivotally connected by its respective opposite ends at 10, 11 and 12, 13 to the bracket member 4 and to the rod or bar 7, respectively. The sides 7, 8, 9 of this hinged or deformable parallelogram are preferably substantially straight. The pivotal connections 10 and 11 of link 8 are located at an intermediate point of the bracket member 4 and the rigid rod or bar 7, respectively. This rigid bar or rod 7, which generally forms that longitudinal side of the hinged or deformable parallelogram which is opposite to said bracket member 4, extends towards the tank 1 beyond the pivotal connection 11 and is pivotally connected at its corresponding end 14 to a stationary supporting or anchoring element 15 consisting for example of a suitable strap, clevis or like fork or yoke-shaped means. The geometrical axis or hinge pin of the pivotal

connection **14** is substantially parallel to the pivot axes or pins **10** to **13** of the hinged or deformable parallelogram and is lying substantially within the plane **5** tangent to the mean surface of the tank wall and extending through the medial point **6** of connection between the bracket member **4** and said tank **1**. The point **6** is therefore located on the vertical straight line passing through point **14**.

If the configuration is assumed to be substantially rectangular, so that the links **8** and **9** are substantially vertical and if then *a* is the distance between point **6** and pivot **10** or between plane **5** and the longitudinal axis of link **8** and if *n.a* is the distance between the pivots **10** and **12** or between the longitudinal axes of links **8** and **9** and if P is the load or force applied by the tank **1** at point **6** of the system **2**, this force P is directed vertically downwards, whereas the supporting reaction at the fixed point **14** is directly opposed to the force P acting at point **6**, i.e. directed vertically upwards and of a magnitude the absolute value of which is equal to this force P. In the state of equilibrium of the system **2**, the link **8** is subjected to an inner compression force of a magnitude equal to: $P\ (1+1/n)$, whereas link **9** is subjected to an inner traction or tension force of a magnitude substantially equal to P/n. The longitudinal sides of the hinged or deformable parallelogram, formed of the bracket member **4** and the rigid rod **7**, undergo a bending moment but the latter is zero at points **6** and **14**.

Moreover, due to the configuration of the pivoted or toggle system **2** with five pivotal connections, the pivot **14** of which connecting the system to a stationary supporting element **15** forming for example a clevis or like means rigidly connected to a fixed bearing structure or foundation **16**, the point **6** is capable of carrying out a substantially plane circular motion or displacement, substantially in parallel relation to the general direction of the plane linkage or toggle system **2** and the axis of rotation of which coincides with the pivot axis **14**, so that the radius of the accurate circular path of point **6** is substantially equal to the distance of point **6** to the pivot axis **14**. This property of relative mobility of point **6** thus enables the free thermal contraction or expansion of the tank depending upon the temperature changes or variations thereof. As already previously stated, the geometrical axis of the pivotal connection **14** assumes a particular well determined position since it must lie within the plane **5** (which is here substantially vertical) tangent to the mean or medial fiber or line of the self-supporting skin or wall forming the tank envelope or shell **1**, at point **6** in the mean normal position or configuration of the plane linkage or toggle system **2**, shown on FIG. **1**, wherein the hinged or deformable parallelogram has substantially the shape of a rectangle the opposite sides **4** and **7** of which are substantially horizontal, whereas its opposite sides **8** and **9** extend substantially vertically.

FIG. **2** shows a modification of the preceding embodiment wherein the connection between the bracket member or beam **4** and the links **8** and **9** is effected through the medium or with the interposition of a heat-insulating material **17**, so that in the case of a tank **1** adapted for example to contain a strongly cooled fluid such as liquefied natural gas at low temperature, such as methane, the whole supporting system **2**, except for the envelope skin or wall of the tank **1** and bracket member or beam **4**, may be made from ordinary steel, i.e. not especially designed for use at low temperature. Under these conditions, the heat-insulation or lagging of the tank **1** may be desirably arranged locally directly on the skin or wall proper of the tank. The heat-insulating pad **17**, interposed between the beam or bracket member **4** and the links **8** and **9** may for example consist of a sleeve, socket, jacket, or like tubular sheath, bushing or casing **18**, for example made of steel, surrounding or enclosing the beam or bracket member **4**, whereas the annular gap or space left between said beam and sleeve is filled, packed or stuffed with a padding of heat-insulating materials **19**. The links **8** and **9** terminate each one at their top or upper end by a clevis, strap, fork or like yoke means, pivotally connected by a pin **10** to **12** to a corresponding lug **20**, forming a fastening bracket or cab integral with sleeve **18** to which it is for example welded.

Other equivalent arrangements may of course be used. Thus for example on FIG. **1**, the pivot pins **10** and **12** through which the corresponding clevis at the ends of links **8** and **9** are pivoted to the beam **4**, respectively, which they partially encompass from below, may be mounted on heat-insulating sleeves extending through the beam **4** and accommodated or housed respectively within a transverse hole thereof, the configuration of each sleeve being such that it thermally insulates the beam **4** from the clevis of links **8** or **9** and from the pivot pin **10** or **12**. This solution offers the advantage to retain the pivot axes **10** and **12** substantially within the horizontal plane **3**.

According to a further alternative embodiment shown on FIG. **3**, the longitudinal side **7'** of the hinged or deformable parallelogram **2'**, which is opposite to the bracket member or beam **4**, is constituted by said rigid stationary supporting element **16**, forming a bearing structure or foundation and the pivotal connection **10'** to **11'** at least one end of the rigid bar or rod **8'** forming the compressed transverse side of the parallelogram, is of the spherical ball and socket or swivel joint type, said end terminating into a rounded tip entering a corresponding complementary hollow cup-shaped recess or like depression formed in the structure to which said rod **8'** is pivotally connected or vice versa. Thus, the rod **8'** may consist of a kind of prop, strut, shore or the like with opposite rounded ends engaging respectively the corresponding hollows, recesses or depressions of the stationary structure **16** and insulating sleeve **17**, whereas the other or opposite transverse side **9'** of said parallelogram which is always under tension, may consist either of a tie rod or brace or of a flexible or yielding connection or bond such as a wire rope, chain or the like, secured to fastening lugs or anchoring clevis or yokes **20**, **21**, integral with the sleeve **17** and bearing structure **16**, respectively.

In the preceding examples, the relative arrangement of fastening lugs, tabs or brackets and of pivot joint clevis or yokes may of course be reversed. Thus for example, the lugs **20** may be provided at the ends of links **8** and **9** on FIG. **2** and be replaced by clevis on the sleeve **17**. On FIG. **3**, the opposite ends of the prop, strut or shore **8'** may each one comprise an endwise recess or depression engaged by a complementary teat, spigot or like projecting portion integral with the sleeve **17** or with the stationary structure **16**, substantially like a vertical supporting bearing.

According to a further embodiment shown in FIG. **4**, said bracket member or beam comprises at least two rotary loose or idler rollers or wheels **22**, **23** spaced longitudinally from each other and in rolling engagement with two roller paths, runways or guide tracks **24**, **25** disposed in mutually confronting or registering relationship and extending in substantially parallel relation to the plane **3** normal to the wall surface of the tank at the point **6** of anchoring of said bracket member **4** to the tank, which plane **3** is here substantially horizontal, i.e. perpendicular to the plane of said toggle linkage or system, said rollers **22** and **23** being located on either side of this plane **3**, respectively, hence of the beam **4**. The rollers **22** and **23** are mounted or rotatably carried by substantially parallel axles **26** and **27** extending transversely of the beam **4** on which said axles are mounted for example through the medium of clevis means or the like **28** integral with the beam.

This system may be considered as being kinematically equivalent to the plane linkage or toggle system **2** or **2'** of the examples shown on FIGS. **1** through **3**. In effect, on the example of FIG. **1**, the points **10** and **12** are relatively movable in space and describe arcs of circumference centered at **11** and **13**, respectively. If it is then assumed that the rod **7** with its pivot points **11**, **13**, **14** and the supporting element **15**, **16** are transferred or shifted to infinity in the vertical direction of links **8** and **9** or in parallel relation to the tangent plane **5**, said arcs of circumference become straight lines which are horizontal or at least parallel to the plane **3** and the pivots **10** and **12** are converted into rollers or wheels.

The runways or guide tracks **24** and **25** are stationary on FIG. **4** and belong to said bearing structure or foundation. On

the contrary, in the alternative embodiment shown on FIG. 5, both runways or guide tracks 24' and 25' are formed of corresponding surfaces of two parallel arms 29, 30, integral with or rigidly connected to a same beam 31 linked or pivoted by its lower end at 14' to a stationary supporting element forming for example a clevis, strut, yoke or fork 15' integral with said stationary bearing structure or foundation 16, the geometrical pivot axis 14' of which is lying substantially within said plane 5 tangent to the mean or medial surface of the tank wall 1 at the point 6 of connection of the bracket member or beam 4 thereto.

While in the embodiment of FIG. 4, both runways or roller paths 24 and 25 assume an absolutely fixed position in space so that their strict parallelism should be achieved with respect to the horizontal plane 3, such a requirement is less imperious in the modification of FIG. 5, since the runways or guide tracks 24', 25', although being necessarily strictly parallel with each other, exhibit a relative mobility in view of their being mounted on the swinging, rocking, tilting or pivoting beam or linked arm 31.

FIG. 6 illustrates the case of a cylindrical tank of revolution 32, mounted for example aboard a ship and the axis of revolution 33 of which is substantially horizontal and parallel to the vertical longitudinal medial plane of the ship. This tank 32 is borne by a series of supports for example in the shape of plane linkages forming hinged or deformable parallelograms 2, distributed in spaced relationship along the trace 34 of the horizontal diametral plane passing through the axis of revolution 33 of the tank. These supports are preferably distributed by or arranged in pairs of opposite supports, disposed on either side, respectively, of the cylindrical lateral wall surface of the tank within transverse or athwartship spaced, parallel planes, respectively perpendicular to the axis of revolution 33 of the tank. On FIG. 6, for the sake of clarity and in order to simplify the drawing, only a few supports 2 have been shown along the lateral wall surface of the cylindrical tank. Further such supports may of course be provided along the horizontal diameter of each one of the circular bottom end walls of the tank.

To assist in supporting the tank in the various lateral inclined, sloping or tilted positions due to the list of the ship during its rolling motion, there are provided further like supports 2*a*, located in spaced transverse or athwartship planes, perpendicular to the axis of revolution 33 and distributed within each one of these planes, along the corresponding, substantially vertical transverse or athwartship circle 35, forming the trace of intersection of said plane with the lateral surface of the cylindrical tank wall. Only some of these supports 2*a* have been shown along two such transverse or athwartship circles 35. Finally, in order to assist in supporting the tank 32 in its various inclined, tilted or sloping positions or trims resulting from the pitching motions of the ship, there are provided still further like supports 2*b* located within separate meridian planes of the tank 32, respectively, and distributed in groups or sets along transverse or athwartship circles lying respectively within substantially vertical planes, perpendicular to the longitudinal axis of revolution 33 of the tank.

FIG. 7 illustrates the case of a spherical tank 36 mounted for example aboard a ship. This tank is supported by a series of spaced supports 2, forming for example hinged or deformable parallelograms, located within separate vertical diametral planes, respectively, and distributed along the great equatorial or horizontal circle 37 of the spherical tank 36. Further or additional supports 2*a* are provided to assist in supporting the tank in its various inclined positions about its axis which is parallel to the longitudinal axis of said ship during the rolling motions thereof. These supports 2*a* are spaced from each other and located within separate meridian planes and distributed along the great circle 38 lying in the vertical plane which is parallel to the longitudinal vertical medial plane of the ship, said meridian planes being perpendicular to said circle. Still further or additional supports 2*b* are provided to assist in supporting the spherical tank 36 in its various inclined positions during the pitching motion of the ship. These supports 2*b* are spaced from each other and distributed along the great circle 39 lying within the transverse vertical meridian plane perpendicular to the longitudinal vertical medial plane of the ship, said supports 2*b* being located respectively within separate meridian planes which are respectively perpendicular to said great circle 39. Here also only a few supports of each type 2, 2*a* and 2*b* have been shown on FIG. 7.

The antirolling and antipitching supports 2*a* and 2*b* are respectively formed with a lighter structure than the main supports 2 which are adapted to directly support the weight of the tank 32 in its normal horizontal position.

In the case of a cylindrical transportation tank such as 32, the axis of revolution of which is approximately parallel to the longitudinal direction of the transportation vehicle such as a ship, i.e. substantially horizontal in a mean normal position, retaining, stop, locking or abutment means 40 are provided to prevent the throwing or toppling over, tipping, dumping, overturning or upsetting under the influence of the movements of rolling and/or pitching. These retaining, stop or locking means consist for example of teats, stubs, spigots, bosses or like parts 40, radially projecting inwards and integral with the outer surface of said cylindrical tank 32 and distributed preferably along at least one of the two respective top and bottom generators which are diametrally opposite to each other within a same substantially vertical meridian plane, each one of said teats, stubs or like projections engaging with clearance the cavity of a stationary hollow or recessed element, forming a socket, sleeve, clevis, cup or the like.

FIG. 8 shows in athwartship cross section such as a cylindrical tank 32 mounted within the hold of a ship 41 only the hull of which has been shown diagrammatically and which tank is supported by said main supports 2 resting or bearing on the double bottom 42 of the hull. This cylindrical tank 32, the longitudinal axis of which is substantially parallel with that of the ship, comprises one or several retaining, stop, locking or abutment means 40, respectively disposed along the upper or top generator and the lower or bottom generator of the cylindrical tank 32 and engaging each one with a given play or clearance a corresponding suitable housing 43 forming an integral part of the ship's structure. The space left between the tank 32 and the walls of the hold are desirably filled with a heat-insulating material 42*a*.

In the various forms of embodiment previously described, the tank is supported, with respect to its weight and substantially vertical components of the various possible accelerations and active, passive, reaction or inertia forces it is likely to undergo, by resting or bearing on at least one outer stationary supporting structure at points located below the horizontal axial, diametral, equatorial or meridian plane of the tank. Accordingly, the substantially vertical rod or link of said parallelogram, which is nearest to the tank, is subjected to a compressive force, whereas the other elongated, substantially vertical and parallel element, forming a link, rod, bar or a flexible connection such as a cable, chain or the like, undergoes a tractive force. Moreover, this system is intrinsically unstable and its stability is obtained only through the cooperation of the full arrangement of supporting device for sustaining the weight as well as the rolling and pitching forces. This is a drawback in particular in view of the increased complexity of the construction and of the arrangement of said supporting devices.

The embodiments according to FIGS. 9 to 13 enable to remove this drawback by the fact that the fastening or connecting, preferably pivoted point of connection of said parallelogram to the outer stationary supporting structure is located above the horizontal, axial, diametral, equatorial or meridian plane of said tank, whereby said tank is either hanging from said supporting structure in its substantially stable condition of balance. Thus, the tank is no longer resting on its supporting devices.

According to a desirable arrangement, said outer stationary supporting structure consists in a reinforcing means forming

an integral part of the top wall or roof defining the space or room containing said tank and formed for example of the main deck in particular with a trunk, casing, shaft or like encasing on a transport ship, a hold of which contains said tank.

Such a device for holding the tank by suspension from above rather than supporting it from below has the following advantages:

1. The equilibrium of each one of the devices holding the tank by suspension from above is stable.

2. Each weight supporting device can be made lighter, with all other conditions remaining unchanged. As a matter of fact, since it is desirable to clear the pivotal connection of each supporting device with the outer stationary supporting structure by spacing this pivotal connection by a sufficient distance from the tank, both substantially vertical sides of said parallelogram should be given a sufficient length, so that the structural dimensioning of the vertical rod subject to compression is essentially determined by the stability requirements under buckling conditions. It is therefore opposite and reasonable that the compressive forces be applied to the least loaded vertical rod which is the rod remotest from the tank. In this modified configuration of the supporting device, the side of the parallelogram which is closest to the tank, undergoes a tractive force of an intensity equal to $P\ (1 - 1/n)$ where P denotes the vertical force applied by the tank to the supporting device and the line of action of which is tangent to the outer tank surface while passing through the horizontal axis of rotation of said pivotal connection, whereas n is the ratio of the distances of both horizontally aligned geometrical vertices of said parallelogram to the vertical plane tangent to said tank and passing through said pivot axis. The other vertical, elongated element, forming a rod or the like, which is remotest from the tank, is on the contrary subjected to a compressive force of an intensity equal to $P \times 1/n$. It results therefrom a weight reduction of the whole assembly of the weight supporting device with respect to the solution advocated in FIGS. 1 to 8.

3. The structure of the tanker-ship containing the hanging tank should be reinforced in order to be able to support the weights of the suspended tanks at a height or level which may correspond substantially to that of the ship's main deck. Such a reinforcement, required by the weights of the tanks, may therefore contribute advantageously to the general reinforcing of the ship's main deck in particular when this deck comprises an encasing, recess or like trunk or hole portion adapted to accommodate or to receive the upper portions of the spherical or cylindrical tanks within a trunk forming a casing or shaft protruding above the main deck.

The same reference numerals as in FIG. 1 to 8 are used hereinafter to designate like or similar portions and parts.

According to the exemplary embodiment of FIG. 9, the cylindrical or spherical tank 1 with a substantially horizontal axis of revolution is suspended from a plurality of supporting devices **102** forming each one a substantially vertical hinged or toggle parallelogram the upper horizontal side 7 of which is pivotally connected at **14** to a stationary hanger element **15** consisting for example of a clevis, yoke or the like which is rigidly affixed to an outer stationary supporting, upper structure **116** consisting for instance of the roof framing of the ship's hold containing the tank or of the main ship's deck.

FIG. 9 may be considered as being in substantially symmetric relation to FIG. 1 with respect to the horizontal plane 3 passing through the horizontal axis of revolution of the tank 1. The tank may be entirely surrounded by a thermally insulating material **42** filling all the space available between the tank and the walls of the surrounding enclosure, so that all the supporting devices are embedded within said insulating material.

In the embodiment shown in FIGS. **10** and **11**, each suspension device **102'** has a parallelogram only partially pivotally connected since its substantially vertical side **108**, which sustains a tractive force or is nearest to the tank **1**, is rigidly integral with both substantially horizontal sides 4 and 7 that it connects and has a flexibility or deformability great enough at least in parallel relation to a substantially vertical or radial or normal plane of said tank to allow free thermal deformation of the latter. Thus, the stretched side **108** may desirably consist of a strip of flat or sheetlike material such as sheet-metal, strip steel or the like, the widest faces of which are substantially parallel to the substantially horizontal axis of revolution of said tank **1**. According to FIG. **11**, each horizontal side **4** or **7** of said parallelogram may consist of two substantially parallel and symmetrical members between which is welded the corresponding end of the element **108** and between which is pivoted the corresponding end of the rod **9**. The strip **108** should therefore exhibit a cross-sectional area large enough to be able to sustain without undue stresses, the tractive forces to which it will be subjected and sufficient give to sidewarping for enabling its free angular deflection under the action of thermal state variations in the size of the tank.

The member **108** may possibly consist of a yielding or a flexible connection such as a chain, cable or the like.

According to the embodiment of FIG. **12**, each aforesaid supporting device k **012** is preferably entirely exposed to the ambient gaseous medium or to the environmental atmosphere while being substantially completely outside the heat insulating system of the tank **1** and its component elements are made from a less noble material than in the reverse case. Thus, the tank **1** may be desirably heat-insulated on the one hand below the horizontal meridian plane **3** by at least one layer or mass of heat-insulating preferably powder material **142**, for instance of the perlite type or the like, filling for example at least the major portion of the free space available between the tank and the wall defining the environmental medium and on the other hand, above said plane **3** by at least one adhesive layer or coating of a relatively more compact and thinner heat-insulating material **142'**, consisting for example of polyurethane directly applied by a spraying process or by a moulding process on the tank skin, in such a manner that each device **102** is substantially entirely free from or clear of the insulating material. Under these conditions, each device **102** becomes accessible for inspection and may be manufactured for example from a less noble steel than in other cases, since it is in direct contact with the environmental atmosphere, hence at a temperature departing less from the ambient temperature than in the other cases.

In a further embodiment according to FIG. **13**, the outer stationary supporting structure **116** comprises a portion or clevis **15** directly in connecting engagement with each supporting device **102** and heat-insulated from the remaining portion of the structure by a layer or block of insulating material **115** interposed between the element **15** and the structure **116** (consisting for example of said ship's main deck).

The antirolling and antipitching supporting device, in particular according to FIGS. **6** to **8**, are not altered by the embodiments of FIGS. **9** to **13**, respectively.

It is to be understood that the invention should not at all be construed as being limited to the forms of embodiment shown and described herein which have been given by way of examples only, as many changes and alterations may be resorted to by those skilled in or conversant in the art without departing from the gist and scope of protection of the invention. In particular the invention comprises all the means constituting technical equivalents to the means described herein as well as their combinations, if they are carried out according to the spirit, principles and teachings of the invention as defined in the appended claims.

I claim:

1. An arrangement for supporting a storage tank having a rigid self-supporting wall the outer surface of which having substantially the shape of a solid of revolution about at least one geometrical axis at least approximately horizontal in the normal position of the tank, comprising a plurality of outer main bearing devices distributed at discrete locations about said tank; a plurality of structural elements each connected firmly to said outer surface of said tank wall and being part of one of said bearing devices and connecting said bearing device

to said tank wall substantially at the level of the horizontal axial plane of said tank in its normal position, said structural elements being disposed in spaced relationship along a corresponding meridian line; a plurality of stationary elements and plurality of connecting means each of said connecting means being a part of one of said bearing devices and connecting said device to one of said stationary elements in such a manner that the vertical lines, issuing from the points of application of the resultant weight components of said tank and of its contents to said stationary elements, respectively, and along which are directed the passive supporting reaction forces statically balancing the weight of said tank and of its contents, are respectively at least approximately tangent to the geometrical envelope surface of the neutral lines of the tank wall at the level of said horizontal axial plane and have their application points lying substantially within said envelope surface; said connecting means having sufficient relative local resiliency mobility to permit free thermal deformation of the tank; each bearing device comprising a pair of said connecting means which are arranged in spaced relationship in such a manner that the straight lines, each of which joins both points of engagement of one connecting means with the structural element and with the corresponding stationary element of said bearing device, respectively, are substantially parallel to each other.

2. An arrangement according to claim 1, wherein each bearing device consists of a system the reduced equivalent geometrical configuration of which is substantially plane and which is deformable and displaceable within a plane which is substantially radial and vertical, i.e. perpendicular to said horizontal meridian plane.

3. An arrangement according to claim 2, for a tank the relative position and orientation proper of which is variable about its center of gravity by various intermittent disturbing movements of rotation shifting it away from its normal position of stable static equilibrium, also comprising at least one set of auxiliary bearing devices and structural elements associated with each separate geometrical axis of rotation, so that at least the points of rigid connection of the elements of each set with said tank are respectively located within a same plane substantially perpendicular to the corresponding axis of rotation and distributed along the trace of intersection of said plane on the tank wall surface for producing additional supporting reactions adapted at least to assist in balancing the weight of said tank and of its contents in its temporarily deviated position.

4. An arrangement according to claim 3, wherein each auxiliary bearing device, associated to an axis of rotation of a disturbing motion, consists of a system the reduced equivalent geometrical configuration of which is substantially plane and which is deformable and displaceable within a plane which is substantially perpendicular to said axis of rotation corresponding to said disturbing motion.

5. An arrangement according to claim 4, for a tank undergoing rolling and pitching movements and mounted on a vehicle the longitudinal, normally substantially horizontal direction of which is substantially parallel to the axis of revolution of said tank, also comprising additional auxiliary bearing devices distributed respectively on the one hand within at least one radial vertical plane, perpendicular to said axis of revolution, along its corresponding circumference of intersection and on the other hand within the vertical meridian plane, along its trace on the tank wall.

6. An arrangement according to claim 2, wherein each aforesaid structural element forms a substantially straight bracket member extending outwards as an elongated projecting arm in overhanging relationship in a substantially radial direction, normal to the outer wall surface of said tank.

7. An arrangement according to claim 6, wherein each aforesaid bearing device consists of a deformable assembly forming a hinged parallelogram linkage, one longitudinal side of which is formed of at least one portion of said bracket member and the opposite side is connected to an outer stationary support, whereas one of the transverse sides, which is axially compressed, consists of a rigid rod and the other transverse side, which is axially under tension, consists of an inextensible tie means.

8. An arrangement according to claim 7, wherein said inextensible tie means consists of a rigid rod.

9. An arrangement according to claim 7, wherein said inextensible tie means consists of a flexible elongated connection.

10. An arrangement according to claim 7, wherein the longitudinal side of said hinged parallelogram, which is opposite to said bracket member, consists of a rigid arm extended towards said tank and pivotally connected by its corresponding end to said stationary support about a pivot axis which is substantially parallel to the pivot axis of said hinged parallelogram and located substantially within the plane tangent to the tank wall and passing through the middle point of connection of said bracket member to said tank.

11. An arrangement according to claim 10, wherein each bracket member is thermally insulated from its connections with the remainder of the associated bearing device, which remainder is made from ordinary steel.

12. An arrangement according to claim 7, wherein that longitudinal side of said hinged parallelogram, which is opposite to said bracket member, is formed of said rigid stationary support and the pivotal connection at least one end of the rigid rod forming said compressed transverse side is of the ball and socket, swivel joint type, said end terminating in a rounded tip engaging a corresponding complementary hollow recessed depression provided in the structure to which said rod is pivotally connected.

13. An arrangement according to claim 12, wherein each bracket member is thermally insulated from its connections with the remainder of the associated bearing device, which remainder is made from ordinary steel.

14. An arrangement according to claim 6, wherein said bracket member comprises at least a pair of rotary loose, longitudinally spaced rollers, and also comprising a pair of mutually confronting guide runways, substantially parallel to the plane normal to the wall surface of said tank at the point of connection of said bracket member thereto and perpendicular to the plane of said system which forms a kinematically equivalent toggle system, said rollers being in rolling engagement respectively with said pair of mutually confronting guide runways and being located respectively on either side of said first-named plate.

15. An arrangement according to claim 14, wherein both aforesaid runways are stationary.

16. An arrangement according to claim 15, wherein each bracket member is thermally insulated from its connections with the remainder of the associated bearing device, which remainder is made from ordinary steel.

17. An arrangement according to claim 14 also comprising a beam pivotally connected to a fixed support the geometrical pivot axis of which is lying substantially within the plane tangent to the main wall surface of the tank at the point of connection of said bracket member thereto, said guide runways forming an integral part of said beam.

18. An arrangement according to claim 17, wherein each aforesaid bracket member is thermally insulated from its connections with the remainder of the associated bearing device, which remainder is made from ordinary steel.

19. An arrangement according to claim 5 for a substantially cylindrical transportation tank mounted on a conveying vehicle having a stationary housing mounted thereon and wherein the axis of revolution is at least approximately parallel to the longitudinal direction of said vehicle, also comprising retaining stop means provided to prevent the upsetting and throwing over of said tank under the action of the rolling and pitching motion of said vehicle said stop means consisting of radially outward protruding projections integral with the outer wall surface of said tank and distributed along at least one of the two diametrally opposed top and bottom generators of the cylindrical lateral surface of said tank, each one of said projections engaging with clearance a cavity of said stationary housing.

20. An arrangement according to claim 10, wherein the point of pivotal connection of said parallelogram to said outer stationary support is located above at least the horizontal axial plane of said tank in its normal position, whereby said tank is suspended from said support in a condition of substantially stable balance.

21. An arrangement according to claim 20, wherein the substantially vertical side of said parallelogram, which sustains a tractive force and is nearest to said tank, is rigidly connected and connects both substantially horizontal sides of said parallelogram and is flexible enough in at least parallel relation to a substantially vertical plane which is normal to said tank to allow free thermal deformation of the latter.

22. An arrangement according to claim 21, wherein the stretched side of said parallelogram consists of a substantially flat strip the widest faces of which are substantially parallel to the substantially horizontal axis of revolution of said tank.

23. An arrangement according to claim 20, wherein said outer stationary support comprises a portion directly in connecting engagement with each aforesaid device and thermally insulated from the remaining portion of said support.

24. An arrangement according to claim 20 also comprising thermal insulation means insulating said tank and wherein each of said bearing devices is exposed to an ambient gaseous medium by being located substantially completely outside of the thermal insulation means, said bearing devices being made of relatively less noble material.

25. An arrangement according to claim 20 also comprising heat insulating means consisting of heat insulation material distributed relatively loosely below the horizontal meridian plane of the tank close to the outer wall thereof and covering in a relatively compact and thinner layer the wall of said tank above said plane, said bearing devices being located substantially outside of said heat insulating means.

26. An arrangement according to claim 20 wherein said tank is located in the hold of a ship, said hold having a top wall, said outer stationary supports being an integral part of said top wall and forming a reinforcement thereof.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,583,352 Dated June 8, 1971

Inventor(s) JEAN ALLEAUME

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the title, reference should be made to the priority of French Application Serial No. 157,299, filed June 28, 1968. This should be in addition to French Application Serial No. 180,260, filed December 24, 1968, which is mentioned in said title.

Signed and sealed this 6th day of June 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334